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OBSERVATIONS AND SIMULATIONS OF THE M-I COUPLING OF BURSTY CONVECTION

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Prepared by:

Ennio R. Sánchez, Senior Research Physicist
Engineering and Systems Division

Prepared for:

ONR
Seattle
1107 N.E. 45th Street
Suite 350
Seattle, Washington 98105-4631

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Approved :

John R. Bramer, Director
Engineering and Systems Division

1 INTRODUCTION

This annual report summarizes the progress achieved in the first year of NASA Grant NAG5-8111, "Observations and Simulations of the M-I Coupling of Bursty Convection."

The ultimate aim of the project is to establish how much of the magnetotail's total potential is due to flow bursts and how much of this potential maps to the ionosphere. In order to quantify these contributions, we need to develop a reliable method to measure the total cross-polar cap potential and the total reconnection rate across the entire polar cap boundary. This was the goal achieved in the first year of the grant. In the following section, we describe in more detail the activities leading to this goal.

2 ACTIVITIES

First, we designed an algorithm to estimate the polar cap boundary from POLAR UVI LBHL images. The algorithm consists of the following steps:

- (1) Subauroral pixels are identified in calibrated UVI LBHL images by a first order guess of the oval equatorward boundary
- (2) A linear fit is performed of the subauroral data numbers versus the calculated solar elevation angle on an individual image-by-image basis
- (3) Estimated solar contribution is subtracted for each image
- (4) Images are mapped onto a PACE geomagnetic coordinate grid
- (5) The high latitude boundary of the auroral oval is determined at a brightness threshold of $4.8 \text{ photons cm}^{-2}/\text{s}^{-1}$ [Baker and Brittnacher, private communication, 1999].

An example of the application of the technique is given in Figure 1. It shows the POLAR UVI image of the oval during a substorm expansion that started at 00:47 UT on 9 February 1997.

The polar cap boundary is determined as the periodic curve that fits the locii of the specified brightness threshold (shown as the white solid contour in right panel of Figure 1). With the curve defined, the orientation and velocity of the polar cap boundary can be quantified at each point. The next step is to measure the electric field distribution in the ionosphere. It is determined from incoherent scatter and SuperDARN radar measurements. Since radar measurements generally do not cover the entire area of the polar cap and auroral oval, they are complemented with the assimilative mapping of ionospheric electrodynamics (AMIE) technique, which is then used to fill the gaps in electric field measurements. In September of 1999, Dr. Ennio Sánchez visited Southwest Research Institute with the specific objective of learning the procedure involved in the application of the AMIE technique so that it could be run locally on SRI International's unix system. As a result, SRI no longer needs to depend on other institutions to apply the AMIE technique in its research efforts.

Given the knowledge of the polar cap boundary orientation and velocity and the electric field at every point, the calculation of the local reconnection electric field in the frame of reference of the polar cap boundary is straightforward and given by the relationship

$$\underline{E}_{\text{rec}} = \underline{B} \times (\underline{V}_n - \underline{U}_n) \quad ,$$

where \underline{V}_n is the ionospheric plasma flow normal to the polar cap boundary, \underline{U}_n is the normal velocity component of the polar cap boundary, and \underline{B} is the ambient magnetic field in the ionosphere. With the electric field defined in the field of reference of the polar cap boundary, we can then determine the net rate of magnetic flux transfer across the polar cap boundary by simply integrating the component of the electric field tangent to the boundary, as shown in Figure 2.

We applied the reconnection algorithm to four periods, sampling diverse solar-terrestrial conditions from weak substorms, to strong substorm activity, to storm conditions. In the first example, several weak substorms occurred in the first four hours of 9 February 1997. During this period, the interplanetary magnetic field alternated in orientation between $B_z = +5$ nT and $B_z = -5$ nT. Figure 3 shows the POLAR UVI image of the oval during a substorm expansion that started at 00:47 UT. The upper left panel of Figure 3 shows the oval in the detector plane of the UVI instrument. The upper right panel shows the image after correction for scattered sunlight and geomagnetic projection. The middle panel shows the boundary projected on a two-cell ionospheric electric field distribution determined from ground-based radar measurements. The lower panel shows the color-coded magnitude of the electric field along the polar cap boundary. Blue shades indicate negative electric field (net plasma flow into the polar cap) and red shades indicate positive electric field (net plasma flow from the polar cap). The blue (reconnection) region spans a 9-hour local time sector during a period of intense (~ 1000 km/s) tailward flows measured in the magnetotail by GEOTAIL.

Three more periods encompassing diverse solar-terrestrial conditions were analyzed. The first (Figure 4) occurred during weakly southward IMF and substorm activity. POLAR was near apogee and hence allowed UVI a full view of the auroral oval. In this example, nightside reconnection occurred within a reduced local time sector that coincided with auroral intensification.

The second example (Figure 5) shows a full oval view toward the end of a period where the IMF had been southward for 12 hours, on 3–4 February 1998. The nightside reconnection potential spans 8 hours local time, but the net potential along the polar cap boundary is only 5 kV because of the merging occurring elsewhere.

The final example (Figure 6) shows intense nightside reconnection produced during a long period of southward IMF that accompanied a storm on 29–30 January 1998. The reconnection region spanned 12 hours local time producing a potential of 63 kV. During that period, GEOTAIL observed multiple bursty bulk flow activity preceding a substorm breakup at 22:40 UT.

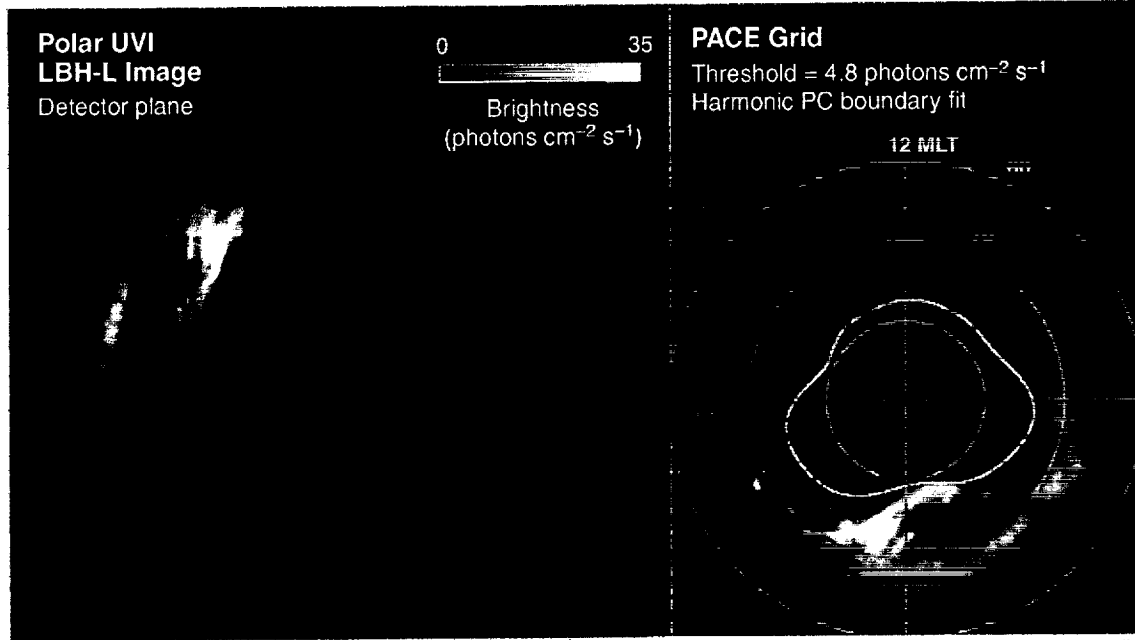


Figure 1. POLAR UVI LBHL calibrated image in the detector plane (left panel). Same image mapped onto PACE grid (right panel). Solid white contour defines the polar cap boundary.

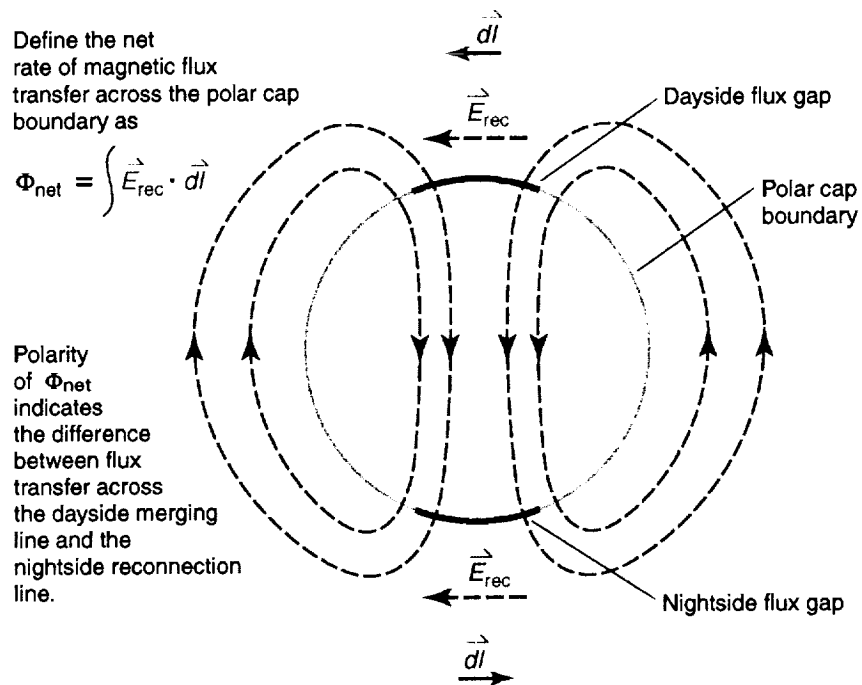
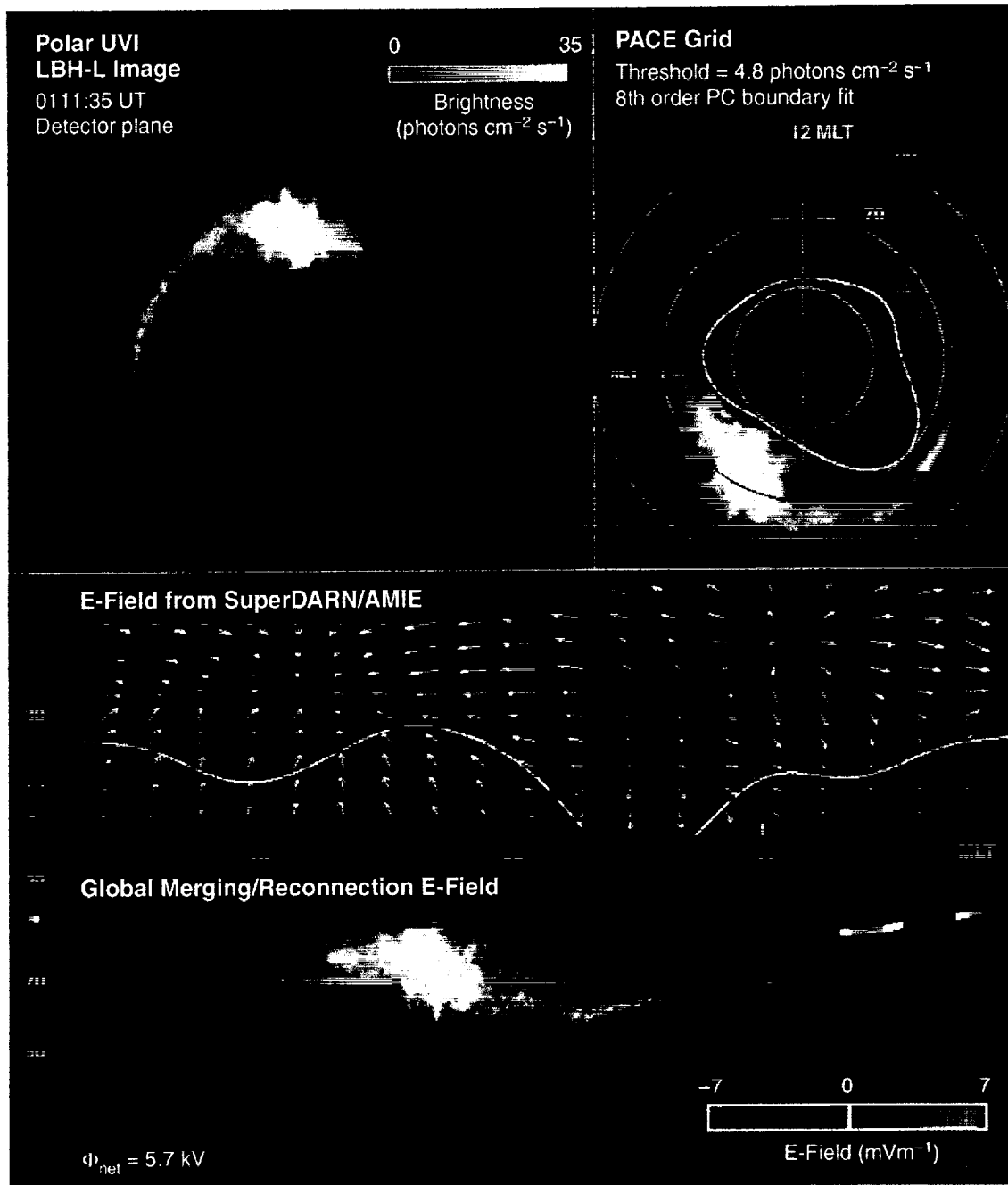
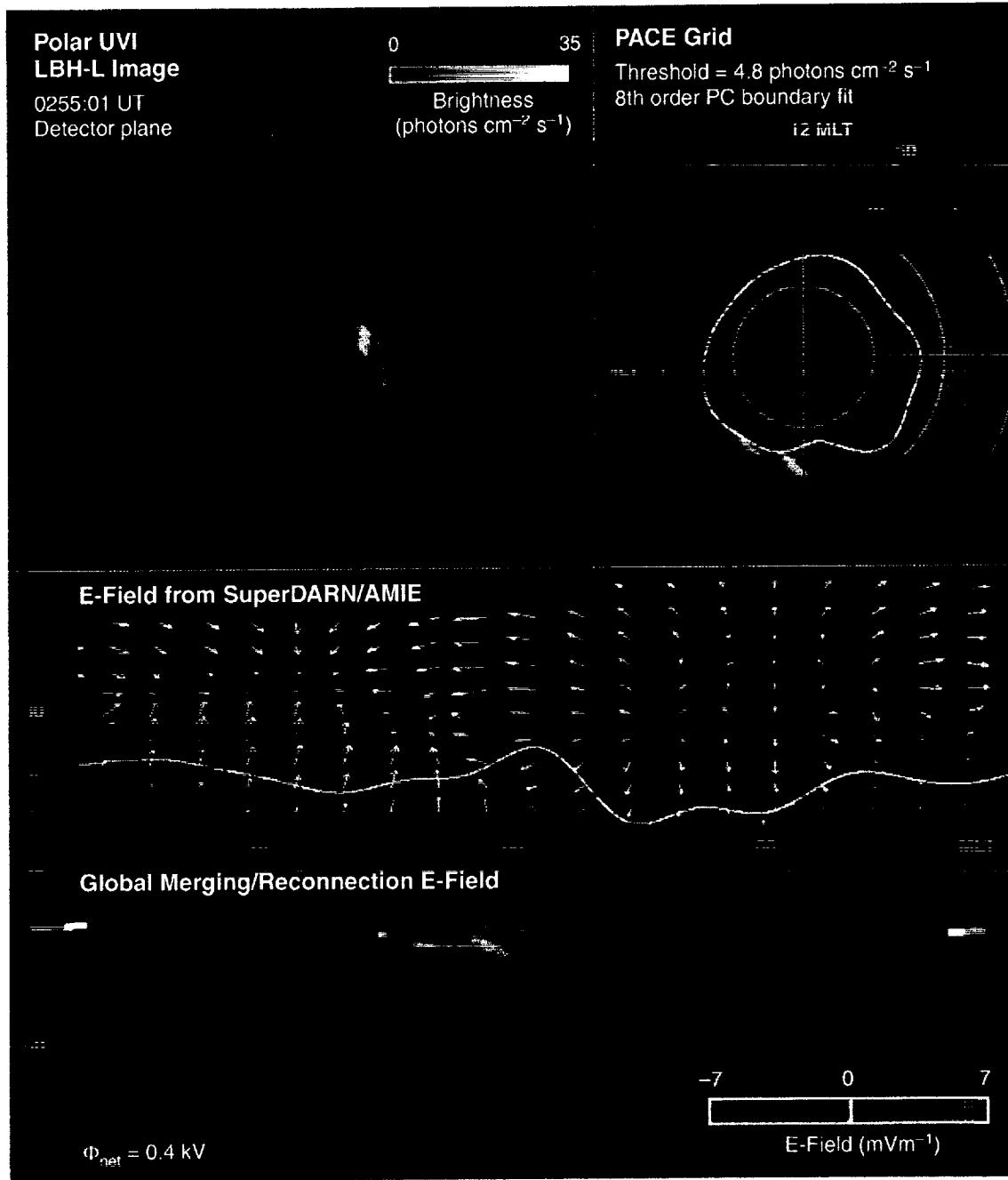


Figure 2. Schematic showing the calculation of the merging and reconnection rates along the polar cap boundary.



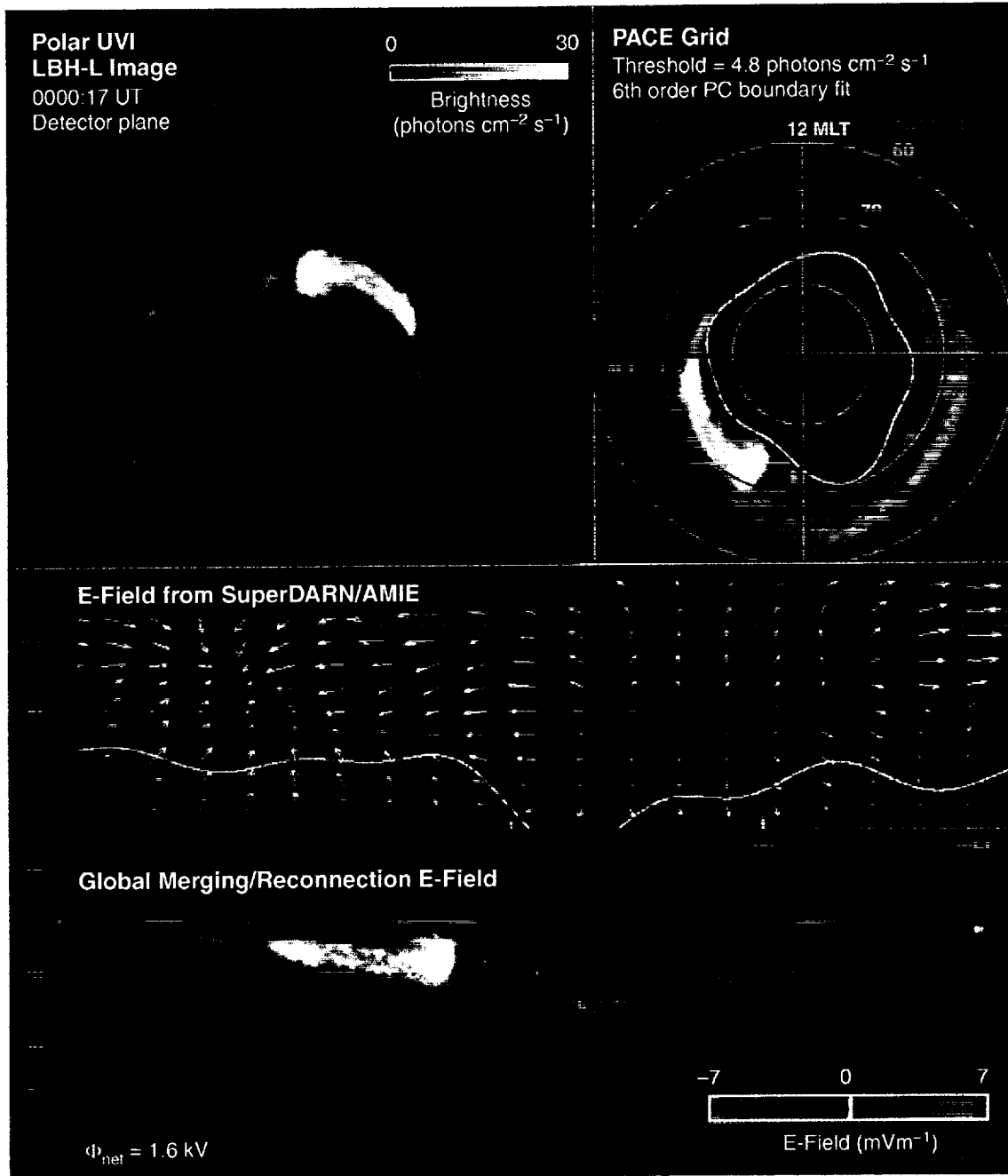
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Figure 3. Four-step sequence involved in the derivation of the merging and reconnection electric field during a substorm expansion on 9 February 1997.



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Figure 4. Full oval view during a period of weakly southward IMF on 2 December 1997.



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Figure 5. Full oval view on 4 February 1998, toward the end of a period where the IMF had been southward for 12 hours.

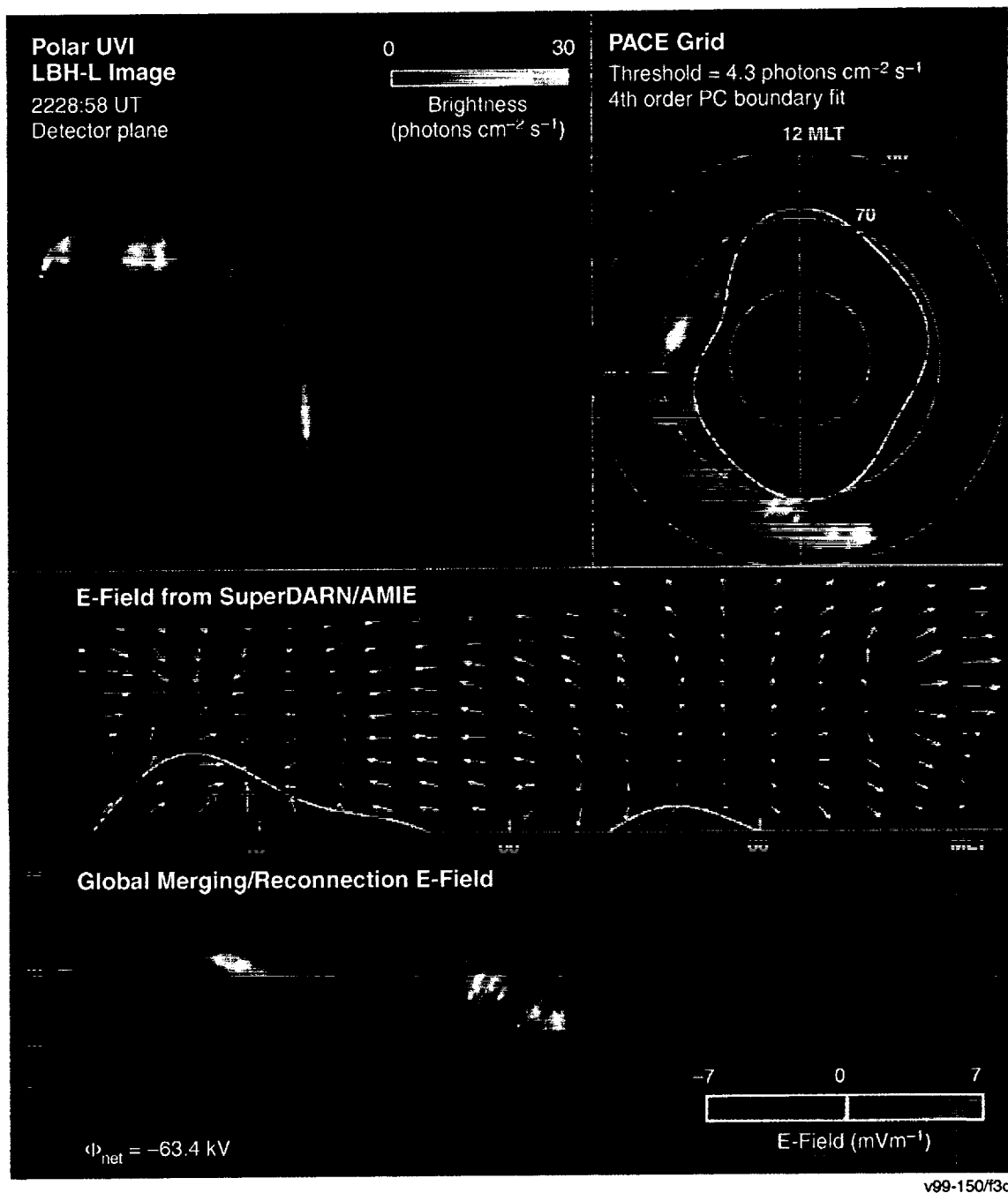


Figure 6. Partial oval view during an intense nightside reconnection episode on 29 January 1998.

First results of the application of the reconnection algorithm were presented at the 1999 Fall AGU Meeting in San Francisco. The title of the presentation is "Autonomous polar cap boundary identification applied to studies of global reconnection rate," E.R. Sánchez, R.A. Doe, K. Liou, J.M. Ruohoniemi, A. Ridley, and J.B. Sigwarth.

A manuscript to be submitted to the *Journal of Geophysical Research* is in preparation. The title of the manuscript is "Measurements of global reconnection rate using POLAR images and ground-based measurements of ionospheric convection," E.R. Sánchez, R.A. Doe, SRI International; K. Liou, JHU/APL; G. Parks, University of Washington; J. Sigwarth, University of Iowa; and G. Blanchard, Louisiana Tech.

3 PLAN FOR COMING YEAR

During the second year of this grant, we will complete a study of the global merging and reconnection properties inferred from the analysis of the four cases mentioned in this report. Also, we will isolate for the same examples, the electric field and current signatures of the ionospheric regions that map to bursty bulk flows observed by GEOTAIL. We will quantify the reconnection potential relative to bursty bulk flows and compare it with the total measured potential. We will apply the merging and reconnection algorithm and the identification of ionospheric electrodynamic properties of bursty bulk flow signatures to additional cases.